Application Note

UCC25640X Benefits in LED Lighting PSU

Adam Lin

ABSTRACT

TI developed LLC controllers over the past 15 years and also developed the LLC controller (TPS9202X) which dedicates for LED lighting PSU application. TI has several years experience in LLC topology and LED lighting PSU. The previous generation devices UCC256302 also promoted to several key LED lighting PSU customers and receives valuable feedback. This application note is a compilation of lessons learned to develop the UCC25640X product and introduces the UCC25640X benefits in LED lighting PSU.

Table of Contents

List of Figures

List of Tables

Trademarks

1 Introduction

LLC topology normally used in the isolation DC to DC stage for the 100W to approximately KW power rating because LLC is the soft switching topology to gain the best efficiency entire loading. This benefit is more significant in the lighting applications because it requires the ambient temperature up to 90℃ but without the air flow for thermal dissipation the LLC topology needs the best efficiency to avoid the power stage component over temperate stress. However, the LLC resonant tank design is not designed for wide input or output voltage range. This application note introduces the resonant tank design for lighting application and how UCC25640X addresses several limitations for the lighting application.

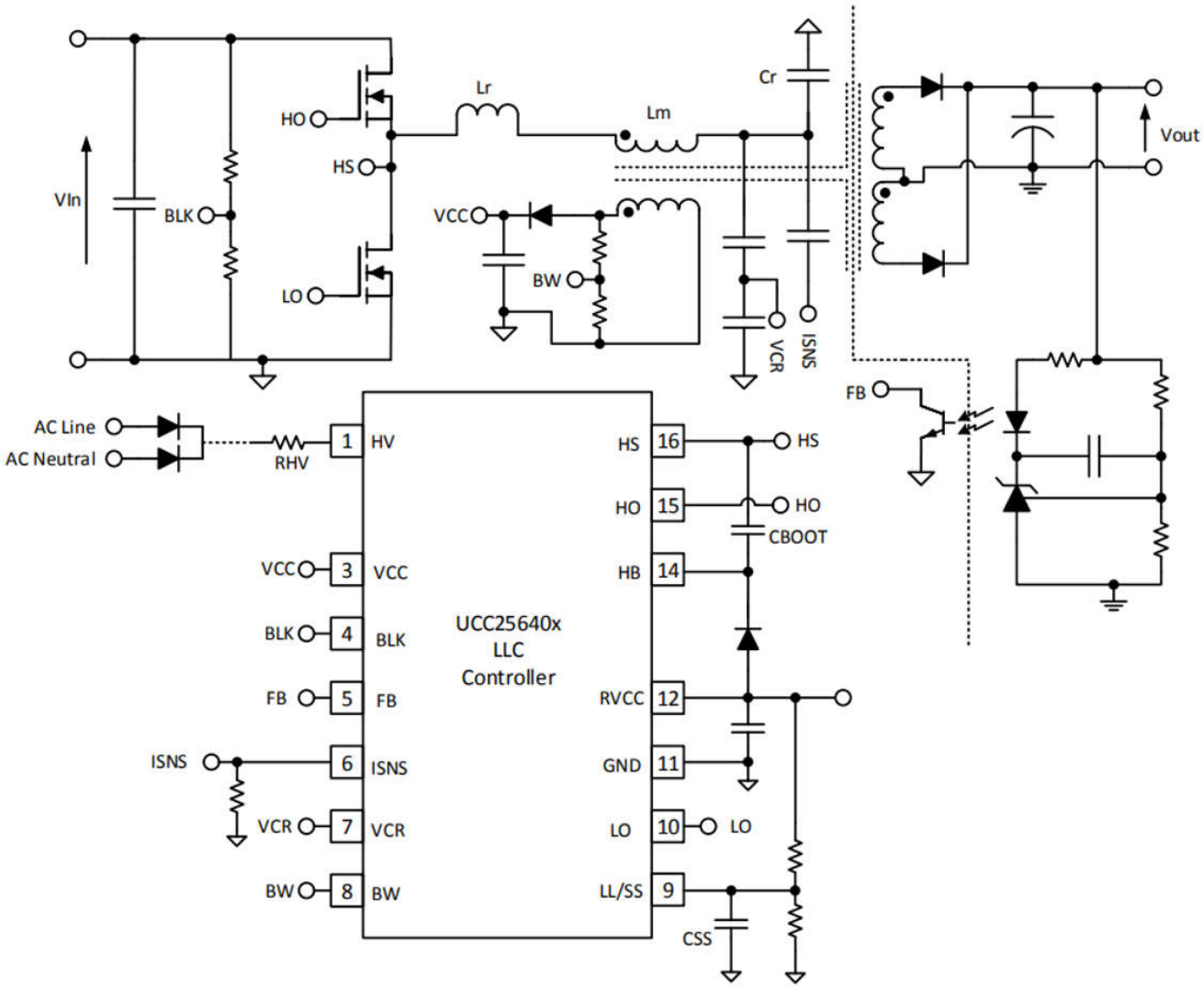

Figure 1-1. UCC25640X Simplified Schematic

2 UCC25640X HS Pin Has Wide dv/dt Sensing Range

As previous mentioned, LED lighting PSU needs to gain the highest efficiency due to thermal concern and the LED also does not have the holdup time requirement so customer increases the magnetizing inductance to reduce the magnetizing circulating current to optimize the efficiency.

LED lighting PSU also needs to support the output voltage range up to two times so resonant tank needs designed for wide gain curve like Figure 2-1 and Figure 2-2 showing. Customers can choose lower Ln to design so the resonant tank curve can be cliffy and can change the Gain a lot with smaller frequency changed.

Designing an LLC Resonant Half-Bridge Power Converterapplication note provides detailed information for designing a resonant half-bridge converter.

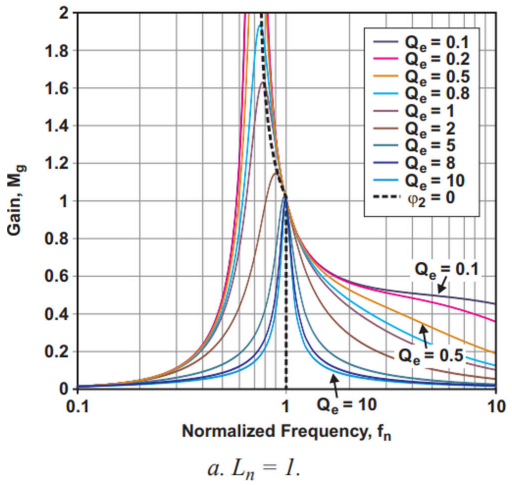

Figure 2-1. LLC Gain Curve LN=1

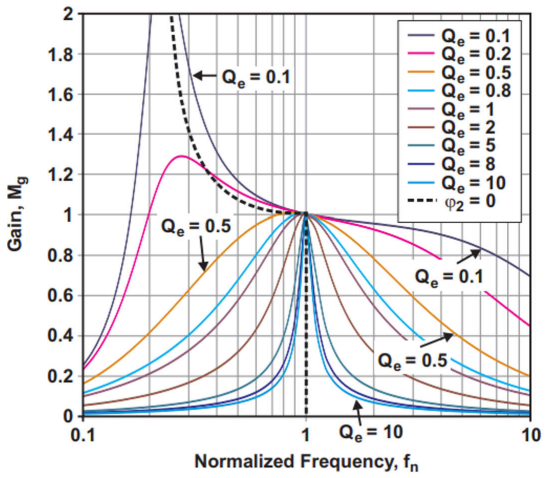

Figure 2-2. LLC Gain Curve LN=10

LED lighting PSU also has special requirements about dimming off function which can turn off the LED by reducing the output voltage.

The LED is similar with the diode because the LED requires minimum forward voltage to be conducted, as Figure 2-3 curve showing so customer can control the voltage feedback loop to let the output voltage lower than minimum forward voltage so LED can be turned off.

However, the switching frequency can be increased a lot during the dimming off condition because LED lighting PSU operates at the no load and low Gain condition so the switching frequency as Figure 2-4 showing.

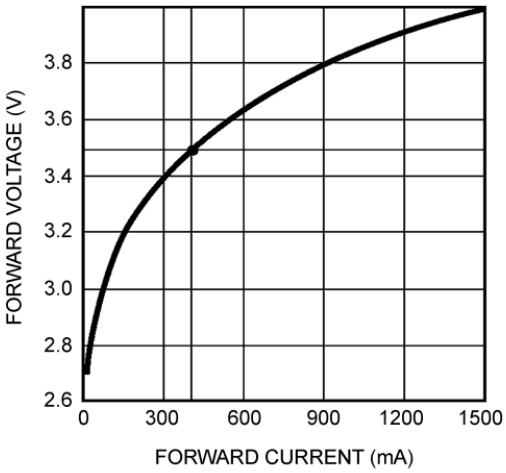

Figure 2-3. LED V-I curve

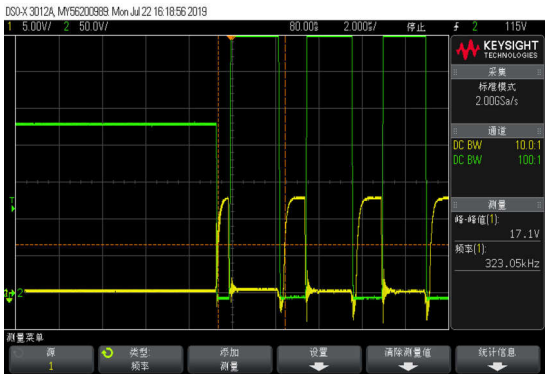

Figure 2-4. Switching Frequency During the Dimming off

If we consider the resonant tank design and dimming off function for lighting application, the resonant current is pretty small during the dimming off condition.

1. Higher magnetizing inductance can reduce the magnetizing circulating current to optimize the efficiency for resonant tank design.
2. Higher switching frequency during the dimming off condition

Customer can also add the capacitor to parallel at MOS drain to source for better the EMI performance so the MOS VDS slew rate can be very slow similar to the Figure 2-5 showing. TI is aware of this issue with UCC25630X at customer board so UCC25640X increases the HS pin dv/dt sensing range and can be designed for LED lighting PSU application.

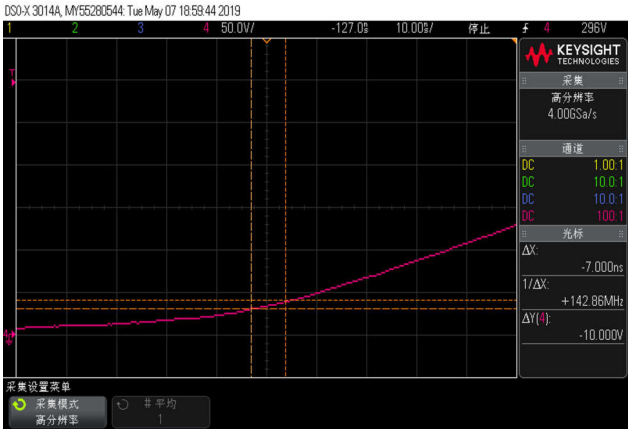

Figure 2-5. MOS VDS Slew Rate

3 UCC256402/4 Eliminating the Need for the Auxpower

UCC256402/4 uses a self-bias start up scheme, thus eliminating the need for a separate auxiliary supply. When AC power is first plugged in, the PFC and LLC are both off. The internal JFET on the HV pin is enabled and can charge the VCC capacitor. The charge current is small when VCC pin voltage is below VCCShort and then becomes larger when VCC pin voltage is above VCCShort. Once the VCC pin voltage exceeds the VCCStartSelf threshold (26 V), the current source is turned off and RVCC is enabled to turn on the PFC. When the PFC output voltage reaches a BLK turn on threshold, then the LLC is turned on. When the LLC is operating and the output voltage is established, the bias winding can supply current for both the PFC and the LLC controller devices.

The power up sequence as Figure 3-1 showing and the UCC25640x LLC Resonant Controller Features Brief Overview and Bring up Guidelines application note introduced the UCC25640X function.

The PFC Vcc is sourced by LLC RVcc pin so LLC can turn off the PFC by disabling the RVcc when LLC triggers the protection to better protect the PFC power stage.

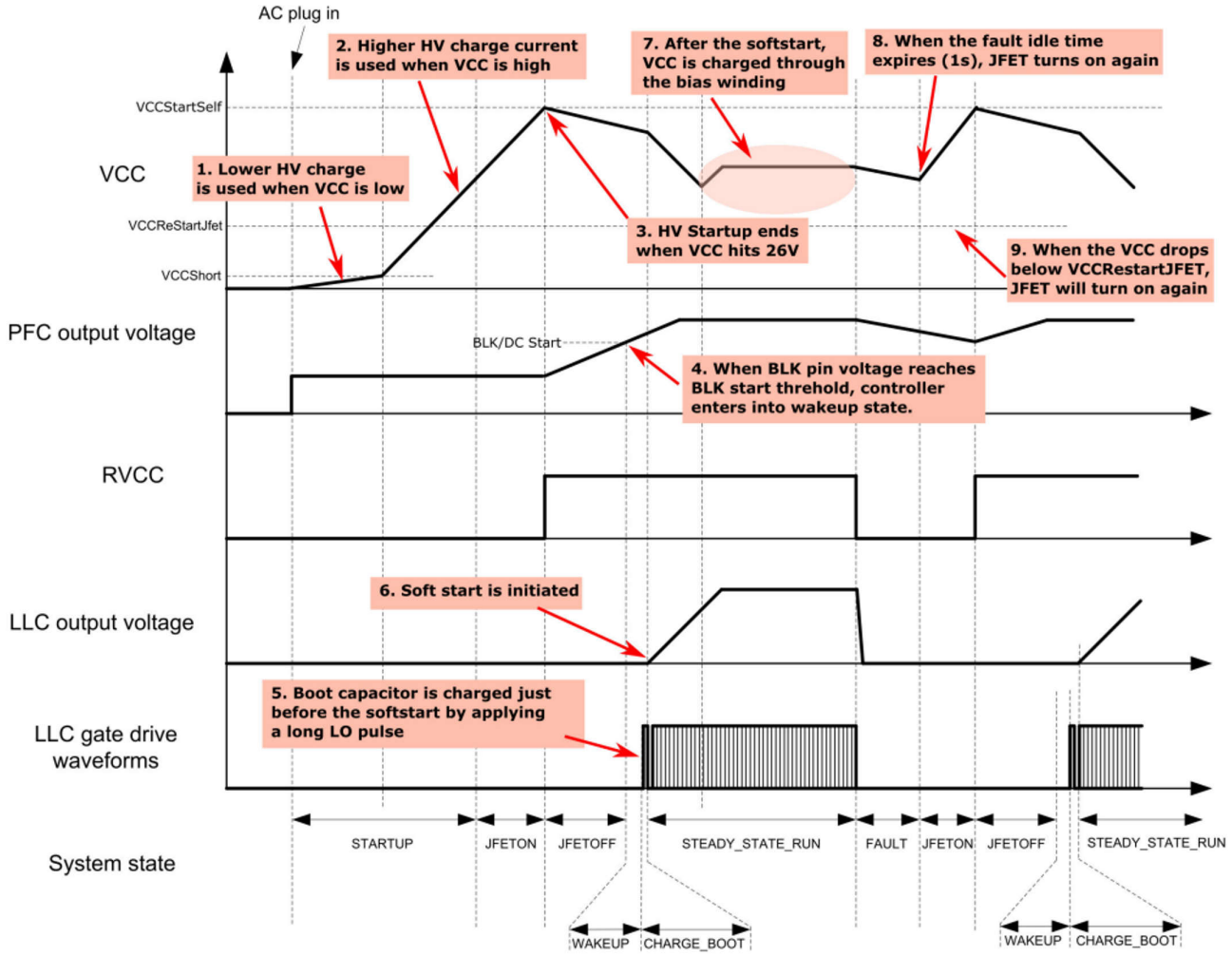

Figure 3-1. Timing Diagram of System State Machine for UCC256402 and UCC256404

4 UCC25640X has Higher Vcc Startup Voltage to Support Lower Vcc Capacitance

Same as previous section that mentioned the Vcc voltage is charged up to Vccstartself threshold (26 V) and then JFET turn off to let Vcc voltage dropped till VCCReStartJfet (9.65 V). If PFC boosts the Vbus voltage to let BLK pin above the BLK start threshold, the PWM can start switching then Auxwinding voltage charge the Vcc so larger Vcc hysister window is helpful to reduce the Vcc capacitance.

This benefit is more significant at LED lighting PSU application because the LED needs to operate at -40℃ to approximately +90℃ ambient temperature without the air flow for thermal dissipation so the Vcc equivalent capacitance can be dropped by low and high ambient temperature as Figure 4-1 showing.

The capacitor bias voltage can also influence the capacitance as Figure 4-2 showing because the LED lighting PSU also needs to support two times output voltage range and the Vcc voltage is up to two times too so the Vcc equivalent capacitance can be dropped during the high output voltage condition.

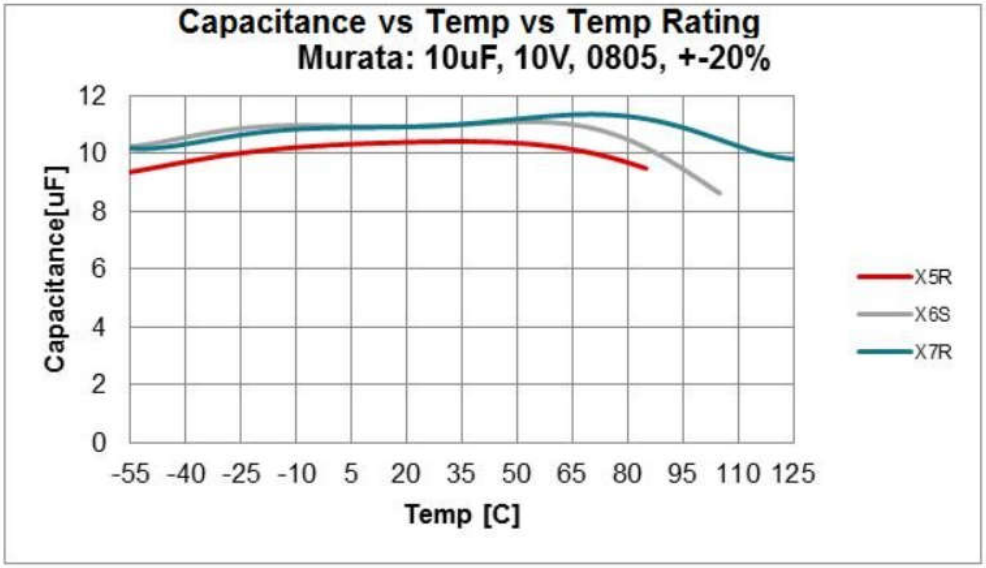

Figure 4-1. Capacitance Versus Temperature

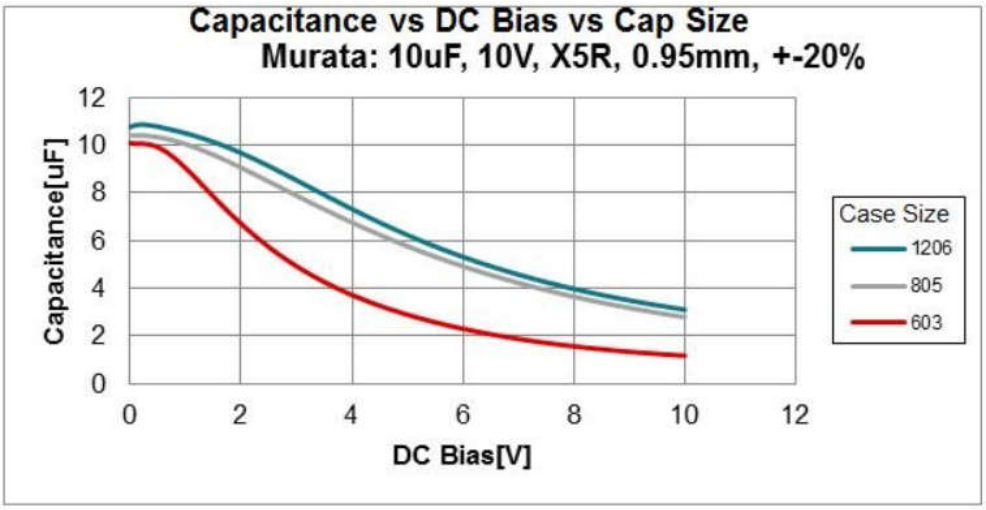

Figure 4-2. Capacitance Versus DC Bias

5 UCC25640X has Programmable Burst Mode Threshold

LED lighting PSU has dimming function to fine tune the output current to control the LED Flux, and the curve as Figure 5-1 showing.

If the LLC operates at burst mode, the output current is not continuing, then the LLC can cause the LED flicking so customer cannot let LLC operate at burst mode within the dimming range.

UCC25640X has LLSS pin to program the burst mode threshold by external resister divider to make this easy to use for customers to fine tune the burst mode threshold and also to disable the burst mode to force LLC continue switching even at no load is helpful to prevent LED flicking.

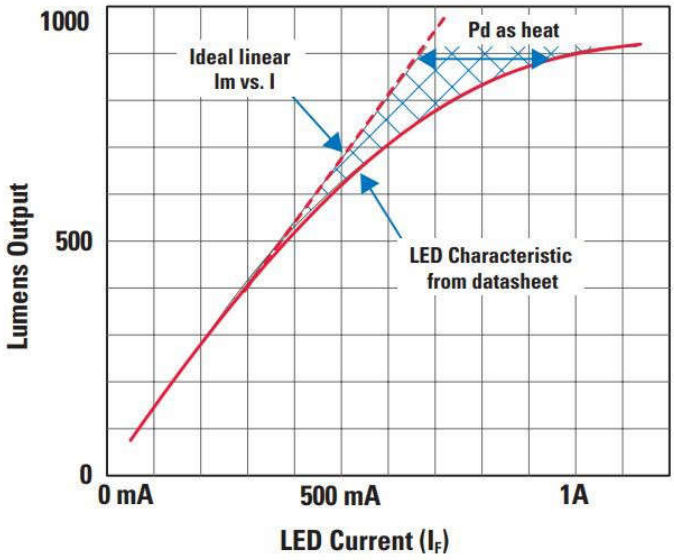

Figure 5-1. Lumens Output Versus LED Current

However, LED lighting PSU still needs the burst mode function to reduce the power consumption during the dimming off.

Same as previously mentioned, LED lighting PSU can control the output voltage to allow the LED to operate at dimming off condition to be able to turn off LED as the standby mode.

The burst mode threshold setting is also important for the dimming off condition and has some trade-off as below.

If the burst mode threshold sets too high, then the Vcc can be dropped to below UVLO threshold during the burst off time and can also allow the controller to operate at burst mode within dimming range.

If the burst mode threshold sets too low, the switching frequency increased and the switching loss increased also where this cannot meet the standby power consumption requirement.

6 UCC256402A Supports Input OVP to Protect PSU if Grid Voltage is Unstable

In some areas, the grid voltage is not stable and the grid voltage even up to two times than normal operation and is observed at the end of customer installment of the system. When there is 3 ph supply available, accidentally, the customer installs between L1 and L2 instead of L1 and N.

Another reason to cause the huge fluctuation in 1ph voltage due to the distribution transformer peak loading leading to >300VAC being common.

UCC256402A senses the bulk capacitor voltage by BLK pin to support the input over voltage protection function when grid voltage is abnormal or even up to two times than normal AC input.

UCC25640X also supports the 700V voltage rating at HV pin and HB pin to be more robust when grid voltage is unstable.

7 UCC25640X has Diversity Version for Each Application

UCC25640X has diversity version to meet different requirement at each application.

See the detailed difference of each device in the following.

- UCC256402: without the Xcap discharge function can support the DC input (lighting and industrial PSU)
- UCC256402A: based on the UCC256402 and add input OVP function.
- UCC256403: without the HV start up function to support the PSU with Aux power (industrial PSU and high-power TV)
- UCC256404: normal AC input application
- UCC256403/4A: based on the UCC256403/4 and output OVP is the latch mode

Table 7-1. UCC25640X Function Comparison Table

Device	Integrated high voltage startup	Integrated X-cap discharge	Require external bias supply	Burst soft on/off	BLK OVP	BW OVP mode
UCC256402	Yes	No	No	No	No	Restart
UCC256402A	Yes	No	No	No	Yes	Restart
UCC256403	No	No	Yes	Yes	No	Restart
UCC256403A	No	No	Yes	No	No	Latch
UCC256404	Yes	Yes	No	Yes	No	Restart
UCC256404A	Yes	Yes	No	No	No	Latch
UCC256404B	Yes	Yes	No	Yes	No	Restart

Table 7-2. UCC25640X Parameter Difference Table

Device	burst package size	BLK start	BLK stop	BLK OVP	Vcc startup voltage	FB pin current source	Highest AC zero crossing detection test current	HB-HS voltage rating
UCC256402	16	3V	2.2V	NA	26V	82uA	NA	17V
UCC256402A	16	3V	2.2V	4V	26V	82uA	NA	17V
UCC256403	40	3V	2.2V	NA	10.9V	164uA	NA	17V
UCC256403A	16	3V	2.2V	NA	10.9V	164uA	NA	17V
UCC256404	40	1V	0.9V	NA	26V	82uA	1.7mA	17V
UCC256404A	16	1V	0.9V	NA	26V	82uA	1.7mA	17V
UCC256404B	40	1V	0.9V	NA	26V	82uA	1.3mA	25V

8 Summary

This application note contains the benefit of using UCC25640X at LED lighting PSU. The key benefit used previously is repeated here.

1. UCC25640X HS pin has wide dv/dt sensing range and is very helpful for LED lighting PSU to optimize the resonant tank design and also adding the CDS for EMI performance.
2. The cost is the top priority for customer, so UCC256402/4 also supports the HV startup to charge the Vcc capacitor by itself, then the customer can save the cost of Auxpower.
3. LED lighting PSU also needs to support wide ambient temperature, and causes the Vcc equivalent capacitance drifted so higher Vcc startup voltage helps to avoid Vcc dropped to UVLO during startup.
4. LED lighting PSU needs to avoid the burst mode to cause the LED flicking, but still needs to minimize the no load power consumption, so programmable burst mode threshold is helpful to balance the trade-off.
5. UCC25640x also has diversity version to fulfill different requirement.

9 References

1. Texas Instruments, *Dimming Techniques for Switched-Mode LED Drivers*, application note.
2. Texas Instruments, *AN-1656 Design Challenges of Switching LED Drivers*, application note.
3. Texas Instruments, *Designing an LLC Resonant Half-Bridge Power Converter*
4. Texas Instruments, *UCC25640x LLC Resonant Controller Features Brief Overview and Bring up Guidelines*, application note.
5. Texas Instruments, UCC25640x LLC Resonant Controller with Ultra-Low Audible Noise and Standby Power, data sheet.
6. Texas Instruments, LDO Basics: Capacitor vs. Capacitance

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265